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EVALUATION OF COMBINED STRESS FACTORS ON HUMANS IN URBAN AREAS

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ABSTRACT

Due to increasing population and urbanization, the necessity for capturing and predicting stress factors on humans rises. Low noise exposure, among others, is widely perceived as a measure for life quality while high noise levels are commonly accepted as a health risk. However, it remains unclear to what extend current noise evaluation methods support the actual emotional state. In an interdisciplinary attempt to determine common factors through statistical analysis, many physical impact factors on the human body in urban areas have been measured and interviews have been performed simultaneously. This contribution will discuss methodology and presents intermediate evaluation results.

INTRODUCTION

The majority of the human population lives nowadays in cities all around the world [1]. As a consequence, urban areas are increasing and man-made influences on the local environment are rising. To predict the outcome of urban development, a comprehensive consideration is required, i.e. to sustain the infrastructural balance in the disciplines of transportation, energy and

communication. More importantly, the effects on the citizen themselves need to be taken into account. Evidently, a more dense population results in an increase of sources for pollution, and also results in an increase of affected individuals.
In order to maintain a high life quality, those effects have to be measured and analyzed, to define new models that can reliably foresee development of urban areas. In terms of noise, this means to introduce and evaluate measures and control mechanisms that put oneself in the position of the affected individual to prevent excessive noise pollution where it may cause harm, i.e. adds a significant share to the overall emotional state as a factor for stress [7].
While conventional noise measurement, propagation prediction and mitigation techniques aim at physically describing sound level using time average over a large time span and combining energy in third-octave or octave bands, the actual noise exposure level for an individual might depart significantly from those values. Especially, if one imagines that a high noise dosage for an urban citizen is assimilated on the duty stroke, during lunch break or on the way home, these noise level are highly time-variant and cannot be evaluated by using daytime or nighttime mean values based on acoustic energy in frequency bands.
To overcome these problems, an all-encompassing attempt to determine stress factors on humans in urban areas requires the simultaneous capturing of influences in a high temporal resolution and, if possible, a valid spatial sampling for interpolation and prediction.
Furthermore, the actual perceptional state of individuals has to be recorded to statistically explore potential connections between physical impact factors and the feelings and sensations of the individual. Within an interdisciplinary project, the RWTH Aachen University advances this field of research by performing acoustical measurements together with meteorological data acquisition in urban areas. At the same time, interview based questionnaires are conducted. In this ongoing campaign, intermediate results from the data acquisition in February 2014 in the city of Aachen are presented in the context of acoustic annoyance [2]. Therefore, the results of parts of the questionnaire with noise annoyance viewpoint are solitarily compared with actual measurement. The procedure is based on user-centered data acquisition where the influences on the individual are raised at the same exact position. This way, comprehensive simulation and prediction can be avoided and the data can be compared immediately [3].

MEASUREMENT AND QUESTIONNAIRE

Meteorological and acoustical influences that may be identified as stress factors have been captured using various types of equipment with independent power supply that can be quickly assembled on-sight. In the vicinity of the recording devices, interviews were conducted with citizens and tourists who passed by, which had proximity to receptor-oriented measurement [8]. It has been meticulously paid attention to the actual location of the participant to establish almost identical meteorological and acoustical conditions, i.e. within a certain radius from the sound level meter or with same amount of direct sunlight etc.

The acoustic measurement has been carried out using a *Norsonic* sound level meter, a *Sennheiser KE4* capsule omnidirectional microphone and a covered binaural artificial head that has been developed at the *Institute of Technical Acoustics* of the *RWTH Aachen University*. While the sound level meter was simply used for verification of captured A-weighted noise level, the sound pressure signals from the omnidirectional microphone and the two-channel artificial head has been captured using a Zoom-H6 multitrack recording device at a sampling rate of 44.1 kHz during the entire time span. The temporal high-resolution capturing is required to determine psychoacoustic indicators such as time-variant loudness for subsequent post-processing. The binaural signals from the artificial head will be utilized as a real-world reference for urban noise simulation and real-time auralization of the situation in the future, i.e. for listening tests. At the beginning of each field measurement a reference signal was recorded using a B&K Calibrator to reference for absolute pressure values. Later, the amplitude from the calibration signal within the

recorded track was used to amplify and transform the waveform into Pascal using the MATLAB® ITA-Toolbox[1] for audio data measurement, processing and analysis.
In a first step the recordings were evaluated using the well-established noise level with applied A-weighting curve. Therefore, the overall mean value was calculated to give a first impression on the resulting noise level at each measurement position. In a second attempt, the loudness was calculated based on the DIN 45631 (1991) standard / ISO 532 B norms (*Zwicker* algorithm) for calculating stationary loudness based one second chunks of time domain data. The average over the entire time period has been determined to obtain another technical indication for each measurement position, which can be compared to the results of the interviews.

On meteorological side, measurements for wind with a 3D sonic anemometer as well as air temperature and humidity were conducted in the center of the park at a permanent station. During questioning, 3D infrared and solar radiation as well as air temperature, radiation temperature, wind (2d sonic anemometer) and data acquisition of particular matter were carried.

Figure 1: Aachen Elisengarten area and surroundings including measurement / interview positions.

For the accomplishment of the interviews and the accompanying meteorological and acoustical measurements, a public space in the City of Aachen has been chosen. Aachen, a city in the very West of Germany with approximately 260,000 inhabitants [4] exhibits a garden-like areal behind the Elisenbrunnen, a half-open neoclassical building that surrounds a geothermal spring of sulphurous hot water. In the immediate vicinity, relaxation places and locations with various functionality can be found, as depicted in Figure 1. In February 2014 during the winter season, at each of the five dedicated locations, interview based questionnaires have been conducted on

[1] ITA-Toolbox, http://www.ita-toolbox.org, original BSD-License, ©ITA, RWTH Aachen University

different weekdays. These locations have been carefully chosen with respect to every common stress factor that may occur, i.e. noise, wind and incidence of light. Additionally, each position intentionally differentiates from their functional meaning within the urban space and is therefore perceived in a distinct context. The aim of the research was to find out, if different stress factors are perceived and accepted more likely by the people with regard to the functionality of the location. For instance, it is quite conceivable that a certain noise level at the bus stop (*Bushaltestelle*, Position C) is not perceived as a stress factor compared to the same value, if occurring at relaxation places such as the cafés around the *Glaskubus* (Positions B) [5].
To gain such qualitative data, an anonymous interview based questionnaire of 50 items has been designed that outlines the user's profile (demographic data), determines social background and identifies the physical well-being of the individual. Furthermore, statements had to be made whether certain solitary influences add to the overall condition, i.e. temperature and humidity of the air.
Concerning acoustics, four inquiries were made using semantic differentiation (in German) with a five-step scale to derive the personal opinion regarding the connotations *loudness (quiet – loud)*, *annoyance (not annoying – annoying)*, *discomfort (discomforting – pleasant)* and *stress (relaxing – stressful)* in the context of the present sound field [6].
A total of 152 citizens participated in the questionnaire (47% male and 53% female) with an average age of 38 years (SD = 20, age range 11-95 years). All participants had the chance of communicating any feedback to our research team.

STATISTIC EVALUATION

The beforehand mentioned questionnaire points targeting the personal evaluation of the acoustic environment have been analyzed for each measurement location separately. In the following, the perception based on the semantic differentials are shown in different graphs along with the acoustic averages of the A-weighted noise level in *dB(A)* (left column, blue line) and the loudness in *sone* (right column, green line). The results of the interviews are shown in each row for a different property in the following order: loudness, annoyance, discomfort, stress.
It has to be mentioned, that an arithmetic mean value has been extracted from the answers of the semantic differentials, that were given a scale from e.g. 1 (silent), 2 (rather silent agreement) 3 (neutral), 4 (rather loud) to 5 (loud). Further analysis of gender, age and health specifics are still in progress.

Especially amongst each other, these rational numbers are not comparable. However, the attentive observer will discover a significant correlation even with the presented arithmetic means on the one hand and the averaged measurement results on the other.

The discussion of the results that can be obtained from the diagrams in Figure 2 will be carried out on a per-location basis, which are depicted in the outline map (see Figure 1).

Münzbrunnen, Location F
The position *Münzbrunnen* was perceived as a rather quiet place. In comparison to all positions, it was even perceived as quietest (m=2.5, SD=1.1). Additionally, the results show a very low value for annoyance (m=1.6, SD=1.2), discomfort (m=1.7, SD=1.2) and stress (m=1.9, SD=1.2). However, the technical evaluation of the acoustic environment expose the highest[2] of all measured average values in dB(A) domain, while the psychoacoustic Loudness value ranges within moderate bounds.

[2] The acoustic data of *location F* did not cover the entire time span of interviews due to technical issues after lunch hour. The average therefore is estimated to a certain extent, and during measurement the acoustic environment appeared to be slightly higher than usual. During lunch hour, an increased occurrence of road cleaning was observed.

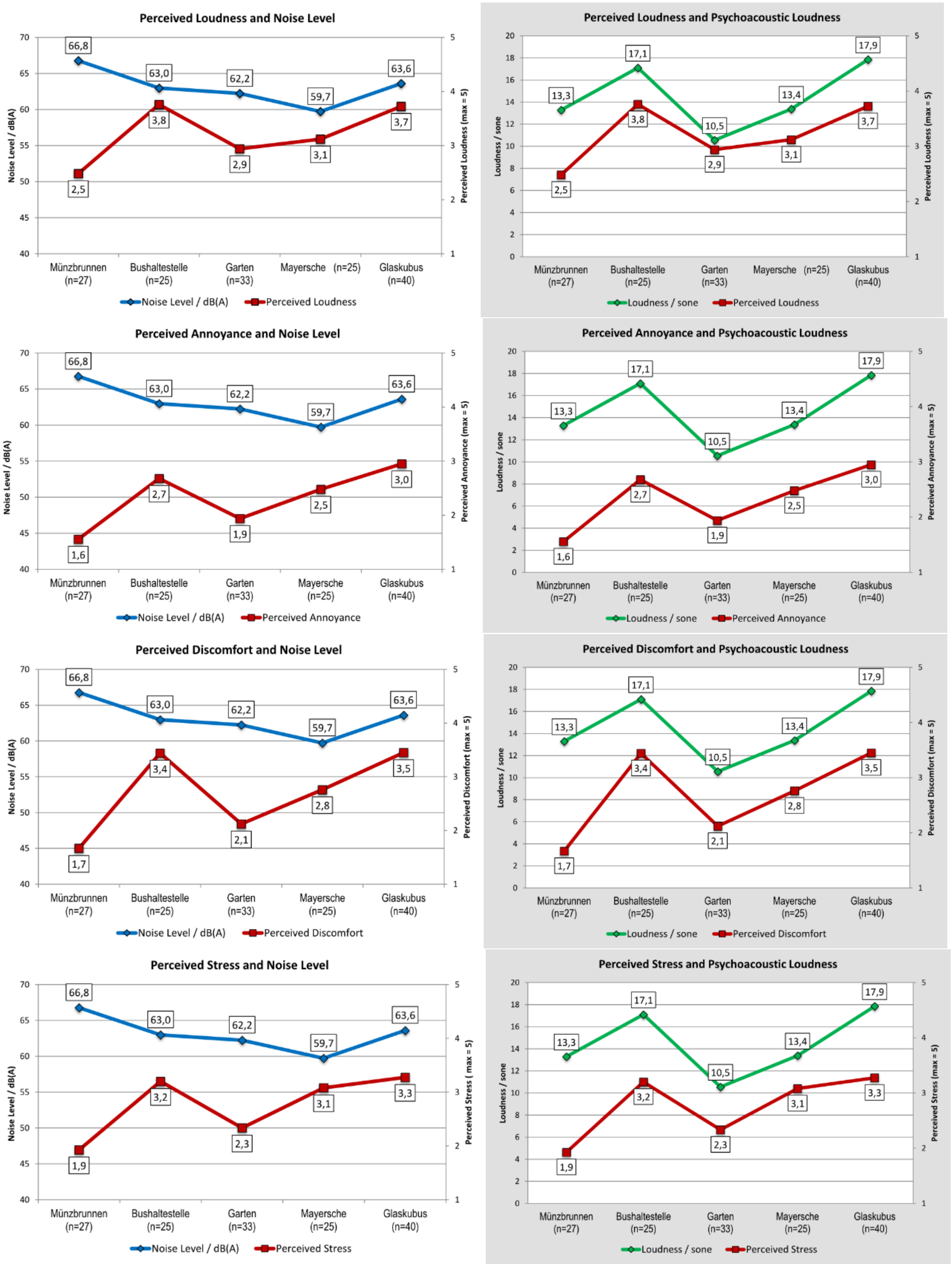

Figure 2: Results of perceived acoustic environment based on questionnaire answers versus classical Noise Level in dB(A) (left column) and psychoacoustic Loudness in soneGF (right column).

Bushaltestelle, Location C
The citizens perceived the position *Bushaltestelle* as a rather loud place, even the loudest place in comparison to the means of all positions (m=3.8, SD=0.8). This position, which is closest to a busy traffic route with high occurrence of busses for public transportation also shows a high Loudness value but a moderate Noise Level. Having this in mind, it is not surprising, that neither discomfort (m=3.4, SD=1.0) nor stress (m=3.2, SD=1.0) were found at low rates in terms of noise sensation. Interestingly, the position was still perceived as rather not annoying (m=2.7, SD=1.5).

Garten, Location E
The position *Garten* was perceived as a rather quiet place (m=2.9, SD=1.2), which was evaluated as rather not annoying (m=1.9, SD=1.2). As can be seen in the tables, the individuals perceived this rather pleasant (m=2.1, SD=1.2) and relaxing (m=2.3, SD=1.0). In an overall comparison, only the *Münzbrunnen* was perceived as even more relaxing, quieter, and more comforting than the *Garten*. The discrepancy between Noise Level and Loudness can be explained easily, because in the garden areal a lot of chatting and sounds from playing children as well as a masking sound from a small fountain occur. All these events add up to the overall noise level, however they are not as distinctive when psychoacoustic measures are applied, which greatly agree with the average numbers that can be extracted from the questionnaire.

Mayersche, Location A
The position *Mayersche* was perceived as rather loud (m=3.1, SD=1.2), but not as considerably annoying (m=2.5, SD=1.6). The sound of this area was perceived reasonably pleasant (m=2.8, SD=1.4), yet also stressful to a certain extent (m=3.1, SD=1.0). As this location is used mainly as an entry to the garden sector and as a pass way to shopping facilities, the interviewees did not consider it as place where one would spend time, hence the moderate results concerning acoustic perception. Interestingly, the *dB(A)* value was determined as low compared to all other positions, while the *sone* value is mediocre. Again, the psychoacoustic measure is found more complying with the human perception at this point.

Glaskubus, Location B
The citizens perceived the position *Glaskubus*, a location with particularly many cafés and bars, as a rather loud place (m=3.7, SD=1.0). It is also the place where the acoustic environment was rated neutral with respect to annoyance (m=3.0, SD=1.6), but it was perceived as a location with negative tendency to comfort (m=3.5, SD=1.3), in comparison to the other locations even as the most discomforting. Additionally, the noise exposition was perceived as particularly stressful (m=3.3, SD=1.3), the top value of all positions. The measurements show good accordance with both methods here, the Noise Level and the Loudness data indicate what can be found in the answers of the individuals. Interestingly enough, this location is almost as close to the traffic route as the position at the bus stop (*Bushaltestelle*) and reveal similar distinct values for the acoustic pollution. However this association is reflected by the psychoacoustic evaluation in a more pronounced way.

The three positions which were identified as rather loud (*Bushaltestelle, Glaskubus, Mayersche*) expose less greenery than the locations in the garden area. Those other two places (*Münzbrunnen, Garten*) which were actually loud in terms of technical values at 66.8 *dB(A)* and 63.6 *dB(A)* noise level, however, were perceived as the most quiet places. This may be a result of the functionality as a relaxation area with vegetation and lawn that additionally do not have any direct line of sight i.e. to the major traffic roads.
The bus stop position (*Bushaltestelle*) was perceived by the citizens as a rather loud, stressful and discomforting place, but still the annoyance response was moderate. This outcome can be explained by the function of the location as a mobility hub for public transportation, which is expected to be more annoying.

CONCLUSION AND OUTLOOK

As an overall conclusion, it can be stated that the Loudness values, even as a mean value over the entire time span, compared to the results from the interview based questionnaire show good agreement. At all locations, the values predict the trend correctly when individuals are asked to give opinion on the acoustic environment with respect to perceived loudness, noise annoyance, discomfort of the present sound field and the stress that is evoked by the noise events.

The acquired high-resolution audio recordings hold a lot of opportunity for post-processing in combination with statistical analysis. A first goal that the authors are targeting in the near future will be the evaluation of every single interview and the data that corresponds to the time span where it was conducted, in contrast to the presented averaging. This renders it possible to account for short-term noise events that may have influenced the individual answers, hence giving indication for occurrences that may have been the reason for an outlier.
In addition, the presence of different stress factors that have been captured apart from the sound environment makes it possible to look for common factors combining the different professions. Diversification of the questionnaire responses using specific user profiles, i.e. by gender and age, may reveal further connections between measured and perceived impacts of noise and is object to future work. In particular, the here presented data will be embedded into a more sophisticated statistical analysis procedure which includes results from the summer campaign, which was recently accomplished, in order to compare the influence of season and it's peculiar weather situations on human perception.

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